

# Recent Advances from BL 4.0.2, A High Resolution Undulator Beamline With Full Control of the Polarization for Spectroscopy and Microscopy

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## INTRODUCTION

Beamline 4.0.2 is the newest undulator beamline at the Advanced Light Source. Equipped with a Sasaki-type Elliptically Polarizing Undulator (EPU) and a high resolution monochromator, this facility is designed to produce high flux beams from <50 eV to >1600 eV with source size spectral resolving powers of 5000-10000. The BL4 EPU allows for full control of the polarization of the x-rays, from linear horizontal, to helical, and linear vertical. A novel feature of the ALS EPU is the capability to rotate the angle of the linearly polarized light. We have also demonstrated a new fast electron-orbit correction system which allows full user control of the polarization at switching times down to 2 seconds between opposite helical polarizations. These capabilities yield a flexible system capable of a variety of linear and circular dichroism experiments. Finally, a new branch has been added to the beamline and a photoemission electron microscope (PEEM) has been installed, making possible the study of magnetic materials on a nanometer scale.

## MAGNETIC CIRCULAR DIOCHROISM SPECTRA OF RARE EARTHS

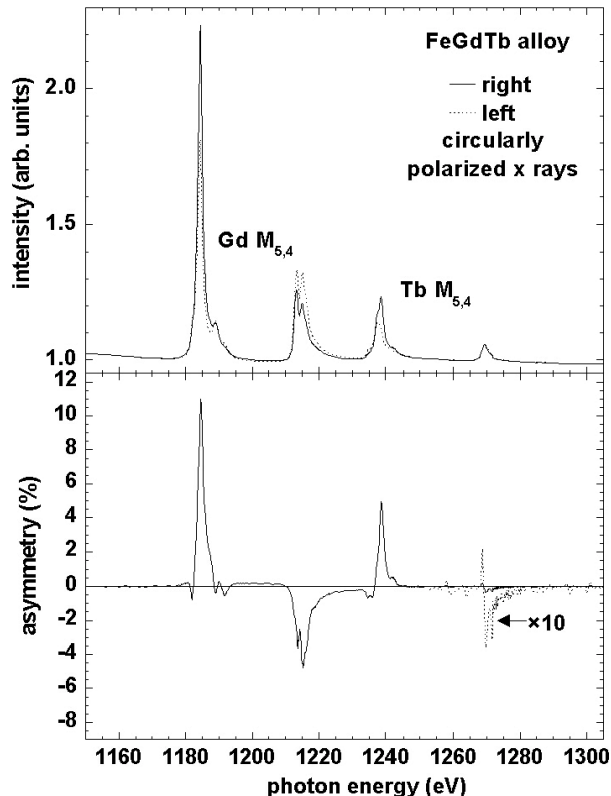


Figure 1 MCD Spectra of Gd and Tb.

Figure 1 shows the magnetic circular dichroism (MCD) spectra of the rare earth elements gadolinium and terbium measured in total electron yield mode from a  $\text{Fe}_{75}\text{Gd}_{25}$  alloy thin film containing a small Tb impurity (sample provided by P. Fischer, Universität Würzburg, Germany). Although the intensity change in the Tb  $M_4$  edge with polarization is normally quite pronounced, a 200 Å Al cap layer and the small Tb concentration result in a MCD asymmetry of only a few tenths of a percent of the total signal at the Tb  $M_4$  edge. However, we are able to detect this small asymmetry unambiguously by switching the polarization of the x rays at each photon energy (switching time 2 s,) eliminating the influence of any long term instabilities of the system from the dichroism signal.

These spectra illustrate that the beamline covers not only the L-edges of transition metals, as shown by Nolting *et al* (see in this Compendium,) but also the  $M_{4,5}$  edges of

the rare earth elements which are interesting because of their diverse magnetic properties. Moreover, the data indicates that very small dichroism effects can be measured. The noise in the asymmetry spectrum is  $<0.05\%$ . The ability to measure small effects is important for studying novel magnetic systems with dilute magnetic species and for materials which show only weak magnetic effects.

## INSTALLATION OF A NEW PEEM ENDSTATION

Figure 2 shows a schematic diagram of the beamline. Newly installed this year are two mirrors, M141, a moveable plane horizontally deflecting mirror, and M142, a cylindrical horizontally deflecting mirror. M141 is mounted on an *in vacuo* kinematic translation stage. To direct the x-ray beam to the PEEM, M141 is inserted into the beampath, sending the x-rays to M142. M142 focuses the beam horizontally yielding a horizontal size of  $60\text{ }\mu\text{m}$ , a reduction of about 10 times compared to the horizontal size in the existing spectroscopy end stations. This arrangement allows for the rapid changeover from microscopy to spectroscopy experiments, and allows the microscope to be in a fixed, permanent position, an important feature for high spectral resolution. A removeable exit slit in the branchline leads to a vertical size of the beam at the PEEM of approximately  $20\text{ }\mu\text{m}$  at a resolving of about 5000 at 700 eV. The first experiments have been performed with this new microscope and are reported elsewhere by Schneider *et al* in this Compendium.

## VARIATION OF THE ANGLE OF LINEAR POLARIZATION

Sasaki-type EPU's are versatile sources of circularly and linearly (horizontally and vertically) polarized radiation. The beamline 4.0.2 EPU has the additional feature that it can produce the linearly polarized x-rays at arbitrary angles. The angle rotation is produced by changing the Z-phase of the EPU in an anti-parallel mode, rather than the parallel mode that produces

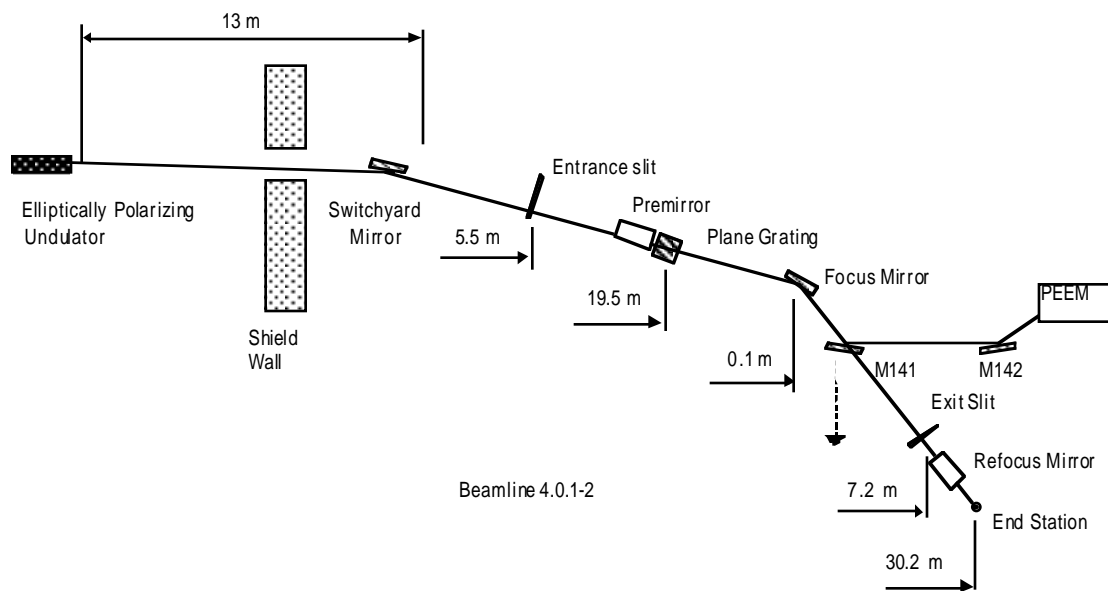


Figure 2 Schematic diagram of BL 4.0.2 showing the placement of two new mirrors, M141 and M142, which direct and focus the x-ray beam to a photoemission microscope endstation. M141 moves in and out of the beampath.

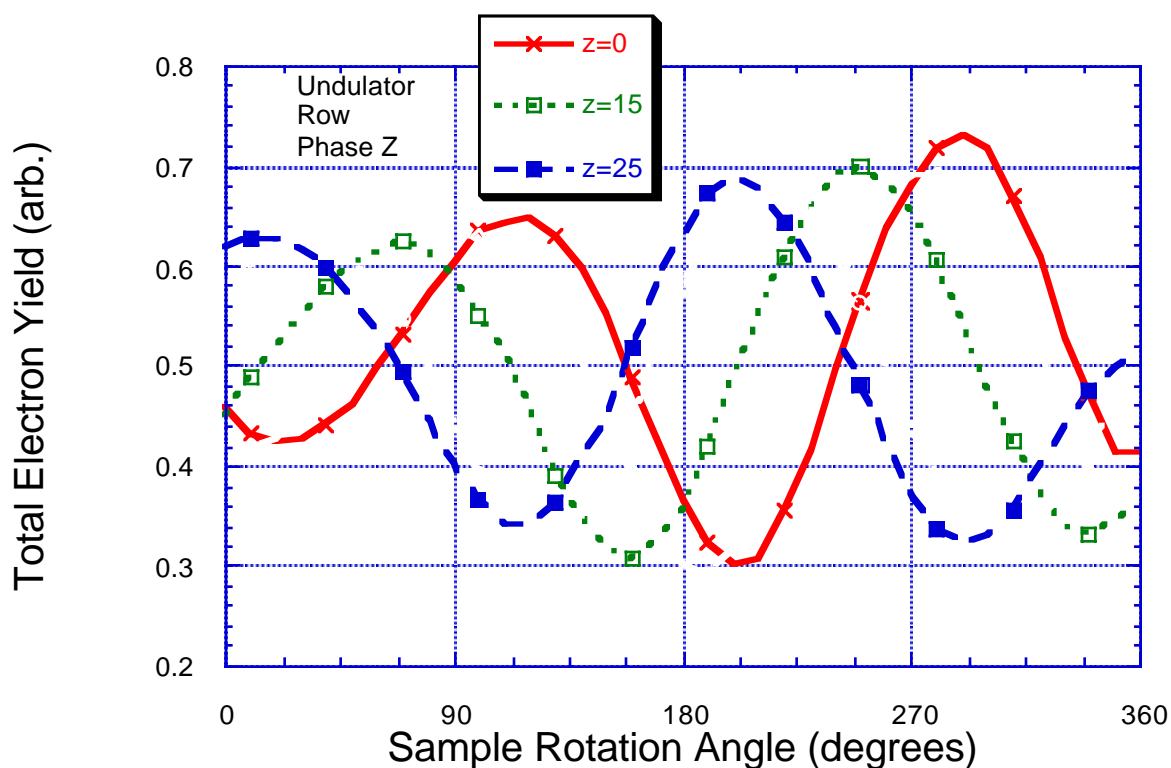


Figure 3 Demonstration of the generation of linearly polarized x-rays at arbitrary angles by the BL4 EPU. Rotation of an oriented Teflon film shows a cyclic total electron yield intensity (Solid line.) Changing the undulator z-phase rotates the angle of the linearly polarized x-rays, which in turn shifts the sample rotation angle giving the maximum intensity. Experiment performed in collaboration with A. Hitchcock, McMaster Univ., and D. Castner, Univ. Washington.

circularly polarized light. Figure 3 illustrates this capability. In this experiment, the total electron yield is measured as a function of the azimuthal angle of the sample, an oriented Teflon film. It exhibits linear dichroism, that is, its spectrum varies as the angle between the linearly polarized x-rays and the orientation of the polymer chains changes. The solid line in Figure 3 shows the total electron yield from the Teflon as a function of its azimuthal angle. The EPU z-phase is set ( $z=0$ ) to produce horizontally linearly polarized at 292 eV. The intensity is cyclic with a period of 180 degrees. The dotted line is a similar sample rotation measurement, but the phase of the EPU has been set to rotate the angle of the linear polarization by about 45 degrees. Note that the signal still has the 180 degree period, but is shifted by 45 degrees. Finally, with  $z=25$ , the polarization is rotated by 90 degrees, giving vertically linearly polarized x-rays. The sample signal shows the same variation with rotation but is shifted by 90 degrees, as expected.

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